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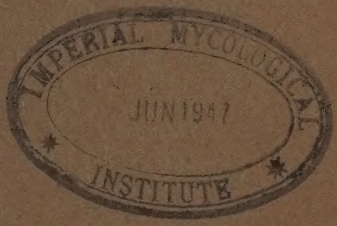

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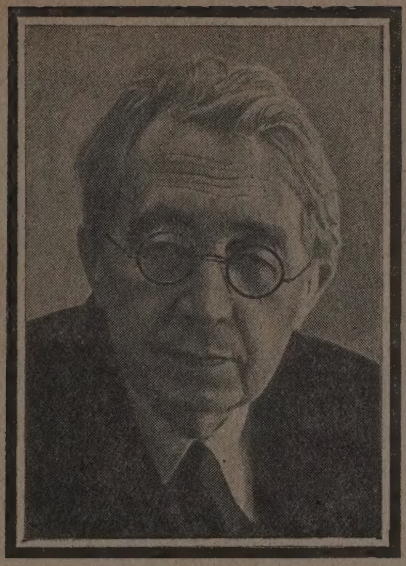

ALEXEY ALEXEYEVICH BORISSIAK

1872—1944

The death of Alexey Borissiak on February 25 at the age of 72 from tuberculosis has deprived our Editorial Board of an old and very active member. In a broader sense it means the end of an untiring and prolific activity in the field of palaeontology and a heavy loss to the scientific world of this country in general, in which A. Borissiak made a prominent and familiar figure. His election to the Academy dates as far back as 1929. He was director at the Palaeontological Institute and deputy-secretary of the Department of Biological Sciences. In 1943 he was awarded a Stalin prize.

The scientific career of A. Borissiak can broadly be divided in two periods. From 1897 to 1910 he was working at the geology of the Donetz basin and the south coast of the Crimea. In course of this work he wrote a series of papers on stratigraphy and tectonics and compiled two large monographs on *Lamellibranchia* and *Cephalopoda*. From 1911 onward his interest centered about the study of fossil mammals. He started with the fauna of Sevastopol discovered by him, then turned to Kazakhstan where he organized excavations, then to the Caucasus and other regions.

It was not long before he became a recognized authority in the palaeozoology of vertebrates.

In the domain of geology his attention was directed to the problem of tectonics. The theory of geosynclines he had evolved after Haug made the basis of his «Geological sketch of Siberia»—the first review of geological data on that country.

In palaeontology the success of his work and its wide significance are due to the fact that he approached the problem of this science from a biological angle. In the early years of his academic life, while yet an undergraduate of the Mining Institute, he attended lectures on zoology at the Leningrad University. When he entered

upon the study of *Lamellibranchia*, his attention was first devoted to the development of recent pelecypods in the Black Sea. As a consistent Darwinian he treated fossil mammals as living beings, and had always due regard to their functional adaptations and evolution.

His ideas Borissiak has lucidly stated in an unpublished manuscript entitled «The problems of phylogenesis in palaeontology», which is now to appear as his posthumous paper. By unremitting propaganda of the principles of biological palaeontology and persistent organization work he was able to build up a school of his own, mainly among the workers of the Palaeontological Institute.

Much attention was also paid by Borissiak to the history of palaeontology (Kovalevsky, Osborn, Dollo). Of particular interest is his inquiry into the life and work of Wl. Kovalevsky. Attaching a great significance to the cultivation of palaeontology among the reading public and the propagation of the evolutional outlook in the sphere of his science Borissiak took lively interest in the cause of dissemination of scientific knowledge and left us a considerable number of popular writings.

Mention needs also to be made of his two textbooks, «Palaeontology» and «Historical Geology», which have won themselves a well deserved fame.

The long years of Borissiak's activity as research worker, teacher and administrator have passed mainly within the walls of the Mining Institute of Leningrad, in the Geological Committee and the Academy. The Palaeontological section of the Geological Committee and the Palaeontological Institute have been created by him.

In this Journal he was active ever since the beginning of the New Series.

The ideas upheld by Borissiak will not pass away with him. They will be developed further by those who profess a palaeontology based on biology and are as surely his followers as he himself was a follower of the celebrated Russian palaeontologist Wl. Kovalevsky.

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MATHEMATICS

SYMBOLIC FORMS OF THE CANONICAL TYPE SEPARATING ONE OR A ROW OF LINEAR FACTORS, AND THE EQUATIONS LINEAR IN JACOBIANS CONNECTED WITH THEM

By G. V. PFEIFFER, Member of the Academy of Sciences of the Ukrainian SSR

Let us consider a linear expression

$$\omega \equiv a_1 dz_1 + \ldots + a_k dz_k - b_1 dx_1 - \ldots - b_n dx_n, \quad b_n \neq 0 \tag{1}$$

a system of linear expressions

$$\begin{aligned}
&\tilde{\omega}_\rho = a_1^\rho dz_1 + \ldots + a_k^\rho dz_k - b_1^\rho dx_1 - \ldots - b_n^\rho dx_n, \quad b_n^\rho \neq 0;\\
&\tilde{\omega}_{\rho-1} = a_1^{\rho-1} dz_1 + \ldots + a_k^{\rho-1} dz_k - b_1^{\rho-1} dx_1 - \ldots - b_{n-1}^{\rho-1} dx_{n-1}, \quad b_{n-1}^{\rho-1} \neq 0\\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\\
&\tilde{\omega}_1 = a_1^1 dz_1 + \ldots + a_k^1 dz_k - b_1^1 dx_1 - \ldots - b_{n-\rho+1}^1 dx_{n-\rho+1}, \quad b_{n-\rho+1}^1 \neq 0
\end{aligned} \tag{2}$$

and a symbolic form of the canonical type

$$\Omega_n \equiv \sum_{\nu} \sum_{\sigma_1 \ldots \sigma_\nu}^{k} \sum_{\tau_1 \ldots \tau_\nu}^{n} M_{\tau_1 \ldots \tau_\nu}^{\sigma_1 \ldots \sigma_\nu} dx_1 \ldots dx_{\tau_1 - 1} dz_{\sigma_1} dx_{\tau_1 + 1} \ldots dx_{\tau_\nu - 1} dz_{\sigma_\nu} dx_{\tau_\nu + 1} \ldots dx_n \tag{3}$$

$$\begin{aligned}
&\nu = 0, 1, \ldots, k && n > k\\
&\nu = 0, 1, \ldots, n && k > n\\
&\nu = 0, 1, \ldots, k = n && k = n
\end{aligned}$$

on which, by using the identities

$$\begin{aligned}
&\Omega_n \equiv \Omega_{n-1} dx_n + \overline{\Omega}_n\\
&\Omega_{n-1} \equiv \Omega_{n-2} dx_{n-1} + \overline{\Omega}_{n-1}\\
&\ldots\ldots\ldots\ldots\\
&\Omega_{n-\rho+1} \equiv \Omega_{n-\rho} dx_{n-\rho+1} + \overline{\Omega}_{n-\rho+1}
\end{aligned} \tag{4}$$

we shall build the forms

$$\Omega_{n-\gamma} \equiv \sum_{\nu} \sum_{\sigma_1 \ldots \sigma_\nu}^{k} \sum_{\tau_1 \ldots \tau_\nu}^{n-\gamma} M_{\tau_1 \ldots \tau_\nu}^{\sigma_1 \ldots \sigma_\nu} dx_1 \ldots dx_{\tau_1 - 1} dz_{\sigma_1} dx_{\tau_1 + 1} \ldots$$

$$\ldots dx_{\tau_\nu - 1} dz_{\sigma_\nu} dx_{\tau_\nu + 1} \ldots dx_{n-\gamma} \tag{5}$$

$$\nu=0,\ 1,\ \ldots,\ k \qquad n-\gamma>k$$
$$\nu=0,\ 1,\ \ldots,\ n-\gamma \qquad k>n-\gamma$$
$$\nu=0,\ 1,\ \ldots,\ k=n-\gamma \qquad k=n-\gamma$$
$$\gamma=1,\ 2,\ \ldots,\ \rho$$

and

$$\overline{\Omega}_{n-\gamma+1}\equiv\sum_{\nu}\sum_{\sigma_1\ldots\sigma_\nu\sigma_{\nu+1}}^{k}\sum_{\tau_1\ldots\tau_\nu}^{n-\gamma}M^{\sigma_1\ldots\sigma_\nu\sigma_{\nu+1}}_{\tau_1\ldots\tau_\nu,\ n-\gamma+1}\,dx_1\ldots dx_{\tau_1-1}dz_{\sigma_1}dx_{\tau_1+1}\ldots$$
$$\ldots dx_{\tau_\nu-1}dz_{\sigma_\nu}dx_{\tau_\nu+1}\ldots dx_{n-\gamma}dz_{\sigma_{\nu+1}} \qquad (6)$$
$$\nu+1=1,\ 2,\ \ldots,\ k \qquad n-\gamma+1>k$$
$$\nu+1=1,\ 2,\ \ldots,\ n-\gamma+1 \qquad k>n-\gamma+1$$
$$\nu+1=1,\ 2,\ \ldots,\ k=n-\gamma+1 \qquad k=n-\gamma+1$$
$$\gamma=1,\ 2,\ \ldots,\ \rho.$$

In calculating the product of the symbolic form (3) by the linear expression (1), we have established the symbol:

$$V^{\sigma_1\ldots\sigma_\nu\sigma_{\nu+1}}_{\tau_1\ldots\tau_\nu\,(n)}\equiv(-1)^\nu M^{\sigma_2\ldots\sigma_{\nu+1}}_{\tau_1\ldots\tau_\nu}a_{\sigma_1}+(-1)^{\nu-1}M^{\sigma_1\sigma_3\ldots\sigma_{\nu+1}}_{\tau_1\tau_2\ldots\tau_\nu}a_{\sigma_2}+\ldots+$$
$$+(-1)^1M^{\sigma_1\ldots\sigma_{\nu-1}\sigma_{\nu+1}}_{\tau_1\ldots\tau_{\nu-1}\tau_\nu}a_{\sigma_\nu}+(-1)^0M^{\sigma_1\ldots\sigma_\nu}_{\tau_1\ldots\tau_\nu}a_{\sigma_{\nu+1}}+(-1)^\nu\sum_{t=1}^{\tau_1-1}M^{\sigma_1\sigma_2\ldots\sigma_{\nu+1}}_{t\tau_1\ldots\tau_\nu}b_t+$$
$$+(-1)^{\nu-1}\sum_{t=\tau_1+1}^{\tau_2-1}M^{\sigma_1\sigma_2\ldots\sigma_{\nu+1}}_{\tau_1 t\ldots\tau_\nu}b_t+\ldots+(-1)^1\sum_{t=\tau_{\nu-1}+1}^{\tau_\nu-1}M^{\sigma_1\ldots\sigma_\nu\sigma_{\nu+1}}_{\tau_1\ldots t\tau_\nu}b_t+$$
$$+(-1)^0\sum_{t=\tau_\nu+1}^{n}M^{\sigma_1\ldots\sigma_\nu\sigma_{\nu+1}}_{\tau_1\ldots\tau_\nu t}b_t \qquad (7)$$

and arrived at the conclusion that the identity of the 3rd sign for separating by the form $\Omega_n(3)$ the linear factor $\omega(1)$ [1] is equivalent to the systems of relations:

$$V^{\sigma_1\ldots\sigma_\nu\sigma_{\nu+1}}_{\tau_1\ldots\tau_\nu\,(n-1)}\equiv-b_n\,M^{\sigma_1\ldots\sigma_\nu\sigma_{\nu+1}}_{\tau_1\ldots\tau_\nu\,n}, \qquad (8)$$
$$\nu+1=1,\ 2,\ \ldots,\ k \qquad n-1>k$$
$$\nu+1=1,\ 2,\ \ldots,\ n-1 \qquad k>n-1$$
$$\nu+1=1,\ 2,\ \ldots,\ k=n-1 \qquad k=n-1$$

It is evident that in considering the forms

$$\Omega_{n-\rho+\gamma}$$
$$\gamma=\rho,\rho-1,\ldots,1 \qquad (9)$$

and the linear factors

$$\overset{\gamma}{\omega}\equiv\sum_{j=1}^{k}a^\gamma_i\,dz_i-\sum_{j=1}^{n-\rho+\gamma}b^\gamma_j\,bx_j,\qquad b^\gamma_{n-\rho+\gamma}\neq0 \qquad (10)$$
$$\gamma=\rho,\rho-1,\ldots,1$$

we had to introduce the symbols

$$V\gamma^{\sigma_1 \ldots \sigma_\nu \sigma_{\nu+1}}_{\tau_1 \ldots \tau_\nu (n-\rho+\gamma)} \qquad \gamma = \rho, \rho-1, \ldots, 1 \tag{11}$$

representing the expressions (7), in which the number n is replaced by the number $n-\rho+\gamma$, and the coefficients of the factor ω (1)

$$a_{\sigma_1}, a_{\sigma_2}, \ldots, a_{\sigma_{\nu+1}}, b_t \tag{12}$$

are replaced by the coefficients of the factors $\tilde{\omega}_\gamma$ (10)

$$a^\gamma_{\sigma_1}, a^\gamma_{\sigma_2}, \ldots, a^\gamma_{\sigma_{\nu+1}}, b^\gamma_t \qquad \gamma = \rho, \rho-1, \ldots, 1 \tag{13}$$

The relations (8) are reduced to the relations

$$V\gamma^{\sigma_1 \ldots \sigma_\nu \sigma_{\nu+1}}_{\tau_1 \ldots \tau_\nu (n-\rho+\gamma-1)} \equiv - b^\gamma_{n-\rho+\gamma} M^{\sigma_1 \ldots \sigma_\nu \sigma_{\nu+1}}_{\tau_1 \ldots \tau_\nu (n-\rho+\gamma)} \tag{14}$$

$$\begin{array}{lll} \nu+1 = 1,2, \ldots, k & & n-\rho+\gamma-1 > k \\ \nu+1 = 1,2, \ldots, n-\rho+\gamma-1 & & k > n-\rho+\gamma-1 \\ \nu+1 = 1,2, \ldots, k = n-\rho+\gamma-1 & & k = n-\rho+\gamma-1 \end{array}$$

$$\gamma = \rho, \rho-1, \ldots, 1$$

The identities (14) allow to build the symbolic forms Ω_n (3) of the most general type having one, two, ..., ρ factors (2) with coefficients assumed beforehand, or, which amounts to the same, having one, two, ..., ρ arbitrary factors (2).

We shall obtain the most general form Ω_n having a linear factor $\tilde{\omega}_\rho$ by replacing in the expression (3) the coefficients

$$M^{\sigma_1 \ldots \sigma_\nu \sigma_{\nu+1}}_{\tau_1 \ldots \tau_\nu n} \tag{15}$$

by their values from the group $\gamma = \rho$ of the relations (14); the structure of this form is as follows:

$$\Omega_n \equiv - \frac{1}{b^\rho_n} \Omega_{n-1} \tilde{\omega}_\rho \tag{16}$$

The most general form Ω_n having the general factors $\tilde{\omega}_\rho, \tilde{\omega}_{\rho-1}$ will be found if in the expression (3) the coefficients

$$\begin{array}{l} M^{\sigma_1 \ldots \sigma_\nu \sigma_{\nu+1}}_{\tau_1 \ldots \tau_\nu, n-1} \\ M^{\sigma_1 \ldots \sigma_\nu \sigma_{\nu+1}}_{\tau_1 \ldots \tau_\nu n} \end{array} \tag{17}$$

are replaced by their values from the groups $\gamma = \rho-1$, $\gamma = \rho$ of the relations (14). In this process the form Ω_{n-1} will separate the factor $\tilde{\omega}_{\rho-1}$

$$\Omega_{n-1} \equiv - \frac{1}{b^{\rho-1}_{n-1}} \Omega_{n-2} \tilde{\omega}_{\rho-1}, \tag{18}$$

$$\Omega_n \equiv \frac{1}{b^{\rho-1}_{n-1} b^\rho_n} \Omega_{n-2} \tilde{\omega}_\rho \tilde{\omega}_{\rho-1} \tag{19}$$

and so on.

Finally, the most general form Ω_n having the linear factors $\tilde{\omega}_\rho, \tilde{\omega}_{\rho-1}, \ldots, \tilde{\omega}_1$ will be obtained by introducing in the expression (3) instead of the coefficients

$$\begin{matrix} M^{\sigma_1 \ldots \sigma_\gamma \, \sigma_{\gamma+1}}_{\tau_1 \ldots \tau_\gamma \, n-\rho+1} \\ M^{\sigma_1 \ldots \sigma_\gamma \, \sigma_{\gamma+1}}_{\tau_1 \ldots \tau_\gamma \, n-\rho+2} \\ \ldots \ldots \ldots \\ M^{\sigma_1 \ldots \sigma_\gamma \, \sigma_{\gamma+1}}_{\tau_1 \ldots \tau_\gamma \, n} \end{matrix} \qquad (20)$$

their values from the groups $\gamma = 1, \gamma = 2, \ldots, \gamma = \rho$ of the relations (14). In this process the form Ω_{n-1} will separate the factors $\tilde{\omega}_{\rho-1}, \ldots, \tilde{\omega}_1$; Ω_{n-2}, the factors $\tilde{\omega}_{\rho-2}, \ldots, \tilde{\omega}_1$; ...; and the form $\Omega_{n-\rho+1}$, the factor $\tilde{\omega}_1$.

$$\Omega_n \equiv \frac{(-1)^\rho}{b^1_{n-\rho+1} \, b^2_{n-\rho+2} \cdots b^{\rho-1}_{n-1} \, b^\rho_n} \Omega_{n-\rho} \tilde{\omega}_\rho \, \tilde{\omega}_{\rho-1} \cdots \tilde{\omega}_2 \, \tilde{\omega}_1 \qquad (21)$$

The corresponding equations, linear in Jacobians, are written down directly.

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ASTRONOMY

ON STABILITY OF STARS

By A. B. SEVERNY

(Communicated by G. A. Shajn, Member of the Academy, 26.X.1943)

The actual distribution of stars on Hertzsprung-Russel's diagram may *a priori* be considered as subject to certain conditions of stability. It would seem that some kind of stability reveals itself also in the permanent character of pulsations observed in stars.

So far astronomers have mainly directed their efforts to the study of s e c u l a r stability. They have found out the conditions for the damping of the pulsations of stars ([1]), and also certain laws of energy production in stars which satisfy these conditions ([2], [3]). Eddington ([4]) is known to have put forward a theory of stars' pulsations. But the very state of equilibrium of a star has not been satisfactorily and rigorously investigated for stability. The well-known condition of stability for the ratio of specific heats, $\gamma > {}^4/_3$, was always obtained either quantitatively or by means of simplifications, leaving much room for doubt as to its applicability to real configurations of equilibrium ([5]).

Within recent years the stability of the equilibrium of individual gaseous spheres without radiation [Emden's spheres ([6])] was studied rigorously for the first time by R. Tolman ([7]) on the principle of minimum total potential energy. Somewhat later his results found confirmation in the works of the present author, in which the problem was treated on the basis of the theory of small motions ([8]). Simultaneously I also made a certain advance in these studies by outlining a method for the investigation of the stability of gaseous spheres with reference to non-radial oscillations and securing some definite data on the stability of white dwarfs([9]). Since then I have been continuing the working out of the problem and have obtained certain results which are reported in the present paper.

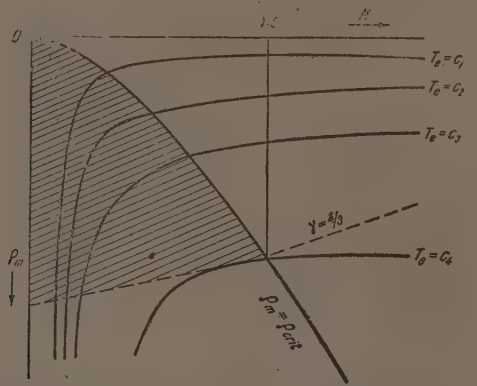
Analytical investigation of small oscillations of polytropic gaseous spheres leads to the following g e n e r a l theorem: gaseous spheres are stable (with respect to radial motions) for a n y polytropic index $n<3$, and unstable for a n y $n>3$. In the case of stable spheres, $n<3$, we have indeed a minimum of total potential energy and a maximum of entropy, by virtue of which these spheres are also stable on variational principles. For stable gaseous spheres the method of Ritz permits the periods of free pulsations to be computed with sufficient accuracy, and it is also possible by using it to find the «period—density» law in the form

$$T\sqrt{\rho_m} = 7.95 \times 10^{-2} \, (\lambda^{(1)} \varkappa)^{-1/2} \qquad (1)$$

where $\lambda^{(1)}$ is the least characteristic number, and $\varkappa$, the ratio of central density ρ_0 to mean density ρ_m; both $\lambda^{(1)}$ and $\varkappa$ depend upon nothing but n. Further, all polytropic gaseous spheres prove to have a bifurcation with respect to non-radial vibra-

tions characterized by a spherical harmonic of order $l=1$, and all of these spheres are stable in vibrations of order $l>1$. It may be inferred from this that such a gaseous sphere is liable to fission as a result of asymmetric free vibration, the more so when its rotation is small. However, the rigorous problems of equilibrium and of the stability of equilibrium in the case of gaseous masses in small rotation call insistently for further inquiry because of their exceptional importance for cosmogony.

The stability of standard stars is controlled by the value of the mean effective compressibility of stellar matter $\gamma=\gamma_t+\gamma_s$ where γ_t and γ_s are determined by the store of thermal and subatomic energy, respectively. As before, we find the condition of stability for standard stars in the form $\gamma>4/3$. This condition, however, imposes limitation also upon the value of subatomic energy and the distribution



of its sources in the interior of the star. Ritz' method gives the «period—density» law for cepheids as

$$T\sqrt{\rho_c}=0.371\,(3\gamma-4)^{-1/2} \qquad (2)$$

which is better in point of completeness than what was found formerly by Eddington (4). Formula (2) agrees satisfactorily with observations. The specific dependence of γ upon subatomic energy and the distribution of its sources is evidence that a standard star may lose its state of stability when there is a large store of subatomic energy with a strong concentration of its sources toward the centre of the star*, and especially if heavy elements enter in great quantities into the composition of the interior layers. This makes unsafe the existence of stars with a very big mass and gives ground to anticipate the loss of stability by the massive giant stars of late spectral classes. As it expends its subatomic energy, the star begins pulsating with increasing regularity, its period decreasing secularly. At the same time the damping of pulsations grows stronger, and the observed dependence between period and amplitude may possibly be interpreted as an evolutionary dependence.

In the case of stars having a mass M larger than $1/10$ of the Sun's mass the main rôle in the dissipation of energy on pulsations is played by radiative conductivity. The study of this question shows that the effect of this dissipative agency is to stabilize the stars with $\gamma<4/3$, if the average density

$$\rho_m<\rho_{crit} \qquad (3)$$

* Under the law of generation of energy, when the efficiency $\varepsilon\sim\rho^m T^n$, stability is guaranteed by the condition

$$m+3n<3+q\beta(3\Gamma-4)/\beta+3(1-\beta)(\Gamma-1)$$

where q is the ratio of thermal to subatomic energy; β is the ratio of gaseous to total pressure; and Γ, ratio between the specific heats of the star's matter.

The parameter ρ_{crit} grows steadily with M (see figure). In the (ρ_m, M) plane stable stars with equal effective temperature T_e fall therefore into two groups: diffuse and extended stars with $\gamma < 4/3$ and dense dwarfs with $\gamma > 4/3$ (the quantity γ grows statistically along the straight line $\rho_m \sim M$ and the place $T_e = \text{const}$ is expressed by the relation $\rho_m \sim M^{-q}$, where $q > 0$).

For the general case of a gaseous star, when there is a deviation from the constitution of the standard model, the curves show a somewhat different topography and the region of the unstable state widens.

A similar separation into two groups of stable configurations is also observed with gaseous spheres without radiaton, but the main dissipative agency is corpuscular viscosity. Here ρ_{crit} depends on the composition of matter (gas or dust particles) as well as on M. The use of ρ_{crit} estimates for primary globulae arising from the gravitational instability of great nebulae and giving origin to stars, leads to the conclusion that the chemical composition of stars at the early stages of their evolution was very nearly that which the interstellar gas is observed to have now.

With gaseous spheres as with stars contractional evolution involving no change of mass and beginning from the diffuse state may eventually bring about a loss of stability when the average density has reached a critical value ρ_{crit}. This is possible if the mass of the star exceeds a certain value $\mathfrak{M}$. Perhaps, we have here opened a prospect for the understanding of Novae.

Sternberg Astronomical Institute.

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APPLIED HYDROMECHANICS

ON THE WORKING OF SUPERCAVITATING SCREW PROPELLERS WITH ALLOWANCE FOR CURLING OF FLOW

By V. L. POSDUNINE, Member of the Academy

In my previous paper (1) I have discussed the subject of supercavitating screw propellers while supposing them to work in a perfect fluid and admitting a number of other conditions. There, a disc theory of the operation of supercavitating screw propellers was evolved without taking the curling of the flow into account, and it was shown, moreover, that they operate very differently in principle from ordinary, non-cavitating propellers.

Now the problem I am presently to discuss, proceeding mainly on the former assumptions and using the same notations, is how the work of supercavitating screw propellers is influenced by the curling of the flow.

The discussion of this problem will be restricted to normal conditions of work, or, strictly speaking, to such as are in accordance with the adopted design. They are set up by supposing the fluid to reach the screw blades without impact and by giving the values for the specific load of the screw propeller ζ and for its relative forward motion λ_0. Supposed to be known are also the main parameters of the undisturbed flow, i. e. the velocity of its forward motion v_0 and the cavitation number σ_0.

Finally, with regard to shape the construction of our screw propellers is specified as follows.

1. The different sections of the screw blades by coaxial cylinders developed on a plane consist of circular arcs where curvature is measured by half the central angle 2φ.

2. The position of the sections of the blades with respect to the plane of the respective disc is determined for different radii by the variable angle of pitch θ, i. e. the angle of installation.

3. The relative pitch $\frac{t}{b}$ of the screw grating expressed in fractions of the blade width b in different sections along the radius is small.

Without leaving the frame of the plane problem, we shall now consider the motion of the fluid through the ring space of the screw propeller, formed by two coaxial cylinders with radii r and Δr, respectively.

With the first of the cylinders developed to a plane we have an infinite screw grating past which the fluid moves with separation of streamlines as is conventionally depicted in Fig. 1, where the inflow and outflow velocities of the fluid in the propeller are represented as coinciding with the tangents to the pressure side of the blades at their respective edges. This form of flow past the blades characterized by the latter receiving no impact when the fluid enters or leaves the screw, is presumably the most advantageous as far as the utilization of energy is concerned.

The impactless entering of the fluid into the propeller is secured by a suitable choice of blade curvature φ, when the angle of pitch θ and the angle of advance α of an element of the blade are assigned some definite values (Fig. 1). As for the fluid leaving the screw without impact, it is a consequence of the smallness of the relative pitch of the screw grating t/b, as specified by the condition 3.

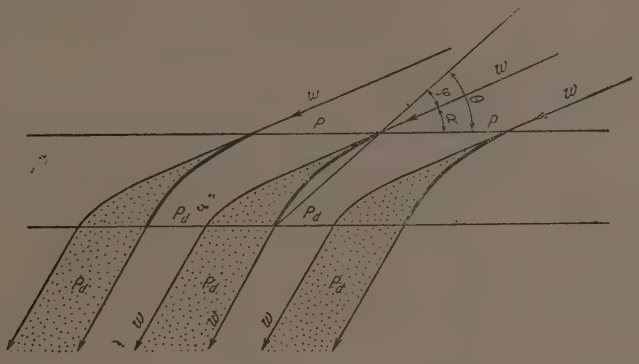

Fig. 1. Flow past screw grating with separation of streamlines

It should be noted, moreover, that the distribution of pressures and velocities in the grating of Fig. 1 and its neighbourhood corresponds exactly to the scheme I have laid down as a basis of my disc theory of supercavitating

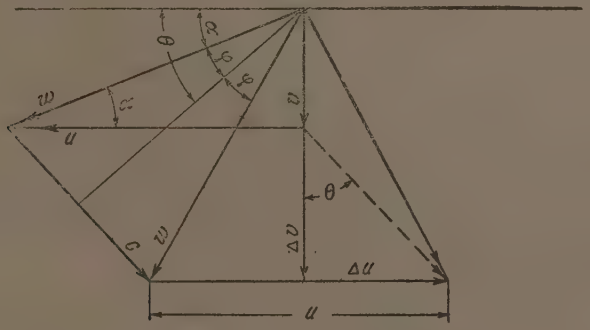

Fig. 2. Velocity triangle

screw propellers involving no curling of flow. In particular, the relative speed of water w in an element of the screw between two neighbouring blades and beyond them is supposed to be constant in accordance with the separation phenomenon.

Taking this and the pattern of the flow past the blades, as shown in Fig. 1, into consideration, let us plot velocity triangles (Fig. 2). In this Figure c denotes velocity which by analogy with a circulation flow past a body may be described conventionally as induced velocity: Δv and Δu are its axial and tangential components, respectively.

We shall now write down the expressions for the thrust ΔS and tangential force ΔT of a ring element of the screw.

Seeing that the curling of the flow has no influence on the thrust, the expression for ΔS may simply be rewritten in one of the formerly derived forms(1). We therefore shall write it thus:

$$\Delta S = m\left(1 - \frac{1}{2}\frac{\Delta c}{v}\right)\Delta v \qquad (1)$$

where $m = 2\pi\rho\, vr\,\Delta r$ is the mass of the fluid passing in unit time through our ring element.

The elementary tangential force ΔT can, if the pressure of water vapour p_d in the cavities is neglected on account of its smallness, be expressed on the basis of the momentum law, in accordance with Fig. 2, in the following simple form

$$\Delta T = m\Delta u. \tag{2}$$

In virtue of formulae (1) and (2) the theoretical efficiency of the screw element η_r may be represented as follows:

$$\eta_r = \eta_{ar} \cdot \eta_{ur} = \left(1 - \frac{1}{2}\frac{\Delta v}{v}\right)\frac{\Delta v}{\Delta u}\frac{v_0}{u} \tag{3}$$

where $\eta_{ar} = 1 - \frac{1}{2}\frac{\Delta v}{v}$ is the axial efficiency of an ideal supercavitating screw, the meaning of which term has been established in my previous paper(1); $\eta_{ur} = \frac{\Delta v}{\Delta u}\frac{v_0}{u}$, respectively, is the tangential efficiency which allows for the influence of the curling on the general value of the theoretical efficiency.

As we know from the earlier work (1) that $\frac{\Delta v}{v}$ is a function of the specific load of the screw $\zeta = k(1+\sigma_0)$, we can rewrite this function for the ring element, adopting the notation $\frac{\Delta v}{v} = 2b$, in the form

$$b = \frac{1}{2}\,\frac{k}{1+\sqrt{1-k(1+k)}} \tag{4}$$

It is easy to realize that the value of the parameter $\frac{\Delta v}{v}$ varies also with the construction of the screw, as determined for the particular ring element by the inclination (angle of pitch) of the blades θ and their curvature φ.

Turning to Fig. 2, this relation may be expressed by the formulae

$$b = \left(\frac{\operatorname{tg}\theta}{\operatorname{tg}\alpha} - 1\right)\cos^2\theta \tag{5}$$

and

$$\operatorname{tg}\varphi = \frac{b}{1+b}\cdot\operatorname{tg}\theta. \tag{6}$$

Proceeding on the notion of the relative advance of the screw $\lambda_0 = \frac{v_0}{Dn}$, where $D = 2R$ is the diameter of the screw, and n, the number of revolutions in unit time, let us take account of formula (3) of the previous paper and write the following expression for the quantity $\operatorname{tg}\alpha = a$ referred to the screw element on the radius $r = Rx$

$$a = \frac{v}{v_0}\frac{\lambda_0}{\pi x} = \sqrt{\frac{1+\sigma_0}{1+4b^2}}\,\frac{\lambda_0}{\pi x}. \tag{7}$$

With the aid of the above formulae, the pitch angles θ of the blades, their curvature φ and, likewise, the value of theoretical efficiency η_r can easily be determined for every element of the screw, if the values of λ_0, ζ, v_0 and σ_0 are given.

Solving the quadratic equation (5) with respect to $\operatorname{tg}\theta$, we obtain after simple transformations

$$\operatorname{tg}\theta = \frac{2a(1+b)}{1+\sqrt{1-4a^2b(1+b)}}. \tag{8}$$

In this formula the radical is given the sign $+$, as for $b=0$ $\operatorname{tg}\theta=a=\operatorname{tg}\alpha$. The condition for tg θ to take a real value is

$$\lambda_0 \leqslant \frac{1}{2}\sqrt{\frac{1}{1+\sigma_0}\cdot\frac{1+4b^2}{b(1+b)}}\,\pi x \qquad (9)$$

This restriction should, of course, be taken into consideration in designing a supercavitating screw on the basis laid down here.

Without dwelling on the determination of the blade curvature φ which is found from formula (6), we go over to the analysis of the quantity η_r. Starting from the velocity triangles (Fig. 2) and using the adopted notations, we rewrite the formula (3) in the form

$$\eta_r = \frac{(1-b)}{\operatorname{tg}\theta}\,\frac{v_0}{\omega r} = \frac{1-b}{\operatorname{tg}\theta}\,\frac{\lambda_0}{\pi x}. \qquad (10)$$

If the quantity a be eliminated from (8) by means of the relation (7) and the resulting expression for tg θ substituted in the formula (10), we shall obtain

$$\eta_r = \frac{1}{2}\,\frac{1-b}{1+b}\sqrt{\frac{1+4b^2}{1+\sigma_0}}\left\{1+\sqrt{1-4\,\frac{1+\sigma_0}{1+4b^2}\,b(1+b)\left(\frac{\lambda_0}{\pi x}\right)^2}\right\}. \qquad (10')$$

The inference to be made from this formula while considering also the equation (4) is that under conditions of flow curling the efficiency of screws of the discussed construction depends explicitly upon the value of the cavitation number σ_0 if the values of the forward motion of the screw λ_0 and the load coefficient k are given.

What has been said here opens the way for the design and experimental investigation of different models of supercavitating screw propellers for working out further the theory of their action.

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GEOPHYSICS

ILLUMINATION OF A HORIZONTAL PLANE AT TWILIGHT AND AT NIGHT

By W. W. SCHARONOW

(Communicated by S. I. Wawilow, Member of the Academy, 10.IX.1943)

The numerous observations of the twilight illumination published in literature are confined to the so-called civil twilight, the time when the Sun is not more than 7° below the horizon. For a deeper position of the Sun no observations were reported until recently.

It is only in 1941 that the first attempts were made by P. Theophilov (1) at studying the night illumination by direct measurements. What is reported in the present paper are the results of systematical observations on the twilight and night illumination, carried out at Elabuga ($\lambda = 3^h28^m$, $\varphi = 55.8°$) during 1942.

During the lighter portion of the twilight interval the observations were made with a luxometer at the later phases and at night, with a special night photometer (2).

A group of standard incandescent lamps with a known illumination had been used for the calibration of these apparatus. Blue filters had been placed in the path of the rays from these reference lamps and before the lamps of the two photometers.

They were chosen to give a spectral distribution close to that of the total daylight (sunlight+skylight). It follows from this that our unit of night illumination is the illumination equal to one lux for daylight vision with a spectral composition corresponding to the total daylight illumination of a horizontal plane under cloudless sky.

The observations have been carried out in the astronomical tower of the building in which the Branch of Leningrad University is stationed. Practically they were not affected by any distorting influence which a town may interpose with its artificial light, smoke, etc.

At twilight the measurements were made every 5 minutes: at night, every 15 minutes. The data thus obtained were worked up as follows. For every night of observation the logarithms of illumination ($\log E$) were plotted against the depth of Sun sinking (D). From this plot those values of $\log E$ were taken which corresponded to round values of D.

Then the results were grouped into averages for equal conditions of weather. The ultimate mean curves for different forms of clouds are referred to in Table 1.

A thorough study of the obtained material brings us to the following conclusions.

1. The curve bringing out the variation of $\log E$ with D at constant cloudiness has always the same character. It bends down as D varies from 0 to 3°, and bulges

Table 1

D	Unit of illumination (lux)	Without snow cover					With snow cover				
		Sky cloudless	Sky with clouds				Sky cloudless	Sky with clouds			
			Ci	Ac	Sc	Ns		Ci	Ac	overcast without snow fall	overcast at snow fall
0°.0		688	—	459	—	244	675	598	589	259	243
0.5		532	520	419	389	131	473	470	473	185	182
1.0	1	498	397	337	301	75	348	365	434	134	141
1.5		291	275	244	260	70	241	239	314	103	151
2.0		207	204	153	186	28	158	152	190	83	107
2.5		144	148	98	126	15	106	196	113	56	70
3.0		963	867	636	899	91	750	735	843	352	359
3.5	10^{-1}	592	526	413	478	71	501	617	525	213	189
4.0		330	293	264	279	47	277	201	276	126	108
4.5		195	194	134	165	30	163	138	146	72	65
5.0		118	100	76	107	17	86	78	91	40	33
5.5		689	578	429	695	82	472	456	525	218	173
6.0	10^{-2}	353	323	210	346	49	263	249	275	115	118
6.5		186	184	127	136	27	134	122	139	66	65
7.0		106	99	78	81	13	78	71	71	38	41
7.5		615	540	490	574	75	443	480	447	184	249
8.0	10^{-3}	373	338	260	328	57	260	264	297	117	153
8.5		204	191	153	168	35	163	147	195	80	89
9.0		123	123	92	108	31	110	116	136	58	55
9.5		855	703	597	540	261	760	760	820	440	300
10.0		501	428	369	342	76	542	373	476	239	146
10.5		244	398	169	227	57	336	238	331	152	100
11.0		146	265	113	165	33	207	161	268	105	72
11.5		85	177	76	114	24	126	110	199	78	49
12.0		56	57	52	74	17	88	73	117	61	33
12.5		37	52	34	47	10	60	49	62	43	26
13.0		26	33	24	31	8	39	34	44	30	23
13.5	10^{-4}	19	27	17	24	6	28	22	35	21	18
14.0		15	21	12	19	6	22	16	25	16	14
14.5		12	16	9	15	5	18	13	18	13	11
15.0		10	14	8	11	4	15	11	13	11	10
15.5		8	11	7	10	4	14	10	12	9	9
16.0		7	9	6	8	3	13	9	10	8	9
17.0		6	8	5	6	3	12	8	8	8	8
18.0		6	8	5	6	3	11	8	8	8	8
Number of curves. .	—	15	4	12	5	4	11	4	7	9	6

therefore away from the axis of abscissae. Between 3° and 10° it runs rectilinearly and the change of log E is 0.5 for every 1°. But from $D=10°$ onwards the decrease of light becomes slower and the curve now bulges toward the axis of abscissae. With $D=17—20°$ the illumination practically comes to its night level and continues so throughout the night. This course the curve shows more or less steadily under any weather conditions (provided the latter do not change during the observation), and only shifts parallel to itself along the ordinate axis in accordance with the degree and form of cloudiness.

2. The average curves for the night display slight regular fluctuations of illumination even at that late period. Much the most often a certain reduction is observed after the Sun has reached a depth of 20°. At $D=25—30°$ we have a vague minimum of illumination. Then an increase begins with a maximum about midnight, then a decrease again, until toward the morning a minimum similar to that obser-

ved at $D=25—30°$ is attained. This run accords with the observations made by Theophilov, except that it is smoother in our case and the amplitude of fluctuations is only 10 per cent.

3. A comparison of the observations made in the evening and in the morning does not display any systematical difference, which fact disproves the claim encountered in textbooks ([3]) that the morning twilight is lighter than that of the evening.

4. Comparisons for cloudless sky in winter and in summer show that if the Sun is 10° below the horizon, the snow cover no longer increases the illumination as it does by day.

On the contrary, the illumination in this phase of twilight is even lower in winter than in summer, probably because the atmosphere is less transparent at that time of the year. For lower positions of the Sun than $D=10°$ the illumination in winter is higher than in summer, and becomes gradually more so as the Sun sinks deeper down until it is two times as high at night. In overcast weather the illumination is always considerably (sometimes 3 to 4 times) higher in winter than in summer whatever the position of the Sun below the horizon.

5. In cloudless weather the twilight illumination for equal sinkings of the Sun varies within a comparatively narrow range; in summer as well as in winter its extreme values do not differ more than 4 to 5 times, and at night in winter the highest value of illumination under these conditions is never more than two times as great as the lowest value. In summer the night illumination shows a much wider range of variation and the highest value may be 10 to 12 times as large as the lowest.

No regularity in these fluctuations has been established for the present; their responsible cause is likewise unknown, but it has been noticed that during the autumn the nights become regularly lighter with the advance from summer to winter.

6. If the above-mentioned mean data for civil twilight ($D<7°$) and cloudless weather in summer are compared with the observations made under identical conditions at Nikolsk in 1932 ([4]), it will be found that they coincide within 10 per cent.

Comparisons with data reported by other workers ([5],[6]) also give a satisfactory agreement. From this it appears that at the stage of civil twilight the illumination is on the average nearly the same in different years and at different points of the temperate zone.

7. Clouds of the *cirrus* form do not affect the twilight illumination if they are outside that segment of the sky occupied by the glow and affect it but little if they are within. In the latter case the clouds of this form can heighten the illumination at certain phases of twilight (for instance, at $D=2.5°$), because light received from the Sun may then render them brighter than cloudless sky. But at other stages they tend rather to reduce the illumination, being themselves darker than the clear sky.

8. Clouds of the *alto-cumulus* type have a pronounced negative effect on twilight illumination in summer, and a slight, more often positive, in winter.

9. The effect of a sky densely covered with low clouds (*stratus* and *nimbo-stratus*) in summer is to reduce the illumination considerably both at twilight and at night, as much indeed as 5 to 7 times, or even more. In winter the reduction due to overcast sky is only 2—2.5 times, because the clouds are strongly illuminated by the reflected light of the snow.

10. Since the illumination displays an insignificant range of variation, when the Sun is more than 20° below the horizon, we can in this case derive its mean values from a larger accumulation of data, using also the observations made during nights of fitful weather or changeable cloudiness.

Table 2 gives these results expressed in milliluxes.

11. If we adopt that the conditions of illumination at the limits of those divisions of the twilight time the beginning and the end of which are given in the astronomical almanachs and ephemerides refer to cloudless weather and snowless

Table 2

Condition of sky	Summer		Winter	
	Mean E	Number of nights	Mean E	Number of nights
Cloudless	0.69	12	0.96	18
Cirrus (*Ci*, *Cc*, *Cs*)	0.64	2	0.71	7
Alto-cumulus (*A*)	0.62	6	0.73	1
Overcast (*St* or *Ns*) without precipitation	0.37	3	0.65	13
Overcast with precipitation	0.20	3	0.62	6

landscape, then rounding up the values of Table 1 we shall receive the following figures:

Division of twilight	$D°$	E (lux)
Civil	6	3.5
»	6.5	2.0
»	7	1.0
Nautical	12	0.006
Astronomical	18	0.0006

Taking these values of E for the photometric limit of a given type of twilight, it is possible, by making use of the remaining columns of Table 1, to find those positions of the Sun below the horizon on which this illumination is reached under other weather conditions, and to compile the tables of the corresponding corrections for the influence of clouds at the beginning and the end of twilight as referred to in the ephemerides.

Table 3

Condition of sky	Brightness in stilbs	
	Summer $\times 10^{-8}$	Winter $\times 10^{-8}$
Clear sky	1.08	2.76
Alto-cumulus	1.03	—
Strato-cumulus	0.99	—
Overcast	0.95	1.95
Cloudless, aurora, horizon	130	—

12. Parallel to the illumination measurements absolute measurements of the brightness of sky on the horizon have been carried out at some nights. One of the purposes of these measurements has been photometrically to establish the boundaries of the astronomical twilight as an instant when the brightness of the horizon is identical in the azimuth of the Sun and at 180° from it. This attempt was a failure because it turned out that at every value of D the horizon was somewhat brigh-

Table 4

Condition of sky	W	
	Summer	Winter
Cloudless	0.85	1.08
Alto-cumulus, night	0.70	—
» » twilight	0.79	—
Strato-cumulus, night	0.51	—
» » twilight	0.65	—
Overcast, night	0.61	0.97
» twilight	0.56	0.95
» moonlight	—	0.90
» day	0.59	0.94

ter in the North than in the South, the brightness ratio in summer averaging 1.38 for $D>20°$.

The cause probably lies in the constant presence of a weak aurora and partly in zodiacal light.

The mean values of the sky brightness for $D>20°$ expressed in stilbs are given in Table 3.

13. In comparing the brightness of the horizon with the illumination we obtain the so-called «weather coefficient»

$$W=\frac{\pi B}{E}\,.$$

Some values of it, as derived from our observations, see in Table 4.

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GEOCHEMISTRY

FERRIC IRON AS AN INDEX OF THE DEGREE OF SERPENTINIZATION OF ULTRABASIC ROCKS

By N. D. SOBOLEV

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In the course of a study of the chemical composition of the ultrabasic rocks of the Caucasus the following regularity could be established: the higher the content of ferric iron in an ultrabasic rock, the more intense is its serpentinization.

As is known, ferric iron isomorphously replaces magnesium in olivine and pyroxenes, rock-forming minerals almost entirely composing ultrabasic rocks. In the course of the serpentinization of these rocks, the olivine and pyroxene pass into purely magnesial serpentine minerals, while the ferric iron being liberated forms an opaque, usually dust-like ore substance, disseminated in the serpentinite.

This substance has usually been taken for magnetite.

When examining the chemical analyses of the ultrabasic rocks of the Caucasus tabulated belov, the ferrous iron of non-serpentinized ultrabasic rocks is seen almost completely to pass into ferric iron in serpentinites. In the table only four chemical analyses of Caucasian ultrabasic rocks are given out of the fifty two available, which also go to confirm the rule stated above.

The chemical analyses of the rocks here discussed, made on material ([1], [2]) from other mining regions of the world, also corroborate this rule.

Generally, the sum of ferric and ferrous iron in ultrabasic rocks and serpentinites ranges from 6 to 12 per cent, while in non-serpentinized rocks the amount of ferric iron makes up about 1 per cent, the rest falling to the share of ferrous iron.

In serpentinized rocks ferric and ferrous iron are present at approximately equal ratios; the prevalence of either of them points to the degree of serpentinization of the ultrabasic rocks: the higher the content of ferric iron, the more intense is the serpentinization of the rock.

In serpentinites the amount of ferrous iron makes up about 1 per cent, the rest being ferric iron.

The proportions of ferric and ferrous iron in non-serpentinized rocks and in serpentinites show that the magnetite formed in the course of crystallization of ultrabasic magma does not change in the process of serpentinization. Unlike this, ferrous iron, liberated during the serpentinization of olivines and pyroxenes, is subjected to oxidation, usually forming a fine-grained, most frequently dust-like, opaque ore substance, generally mistaken for magnetite. Hence it follows that it would be more correct to apply to it the name of haematite.

An essential question thus arises, *viz.* as to the source of supply of the oxygen necessary for the oxidation of ferrous iron. As is known, in the process of metamorphization of ultrabasic rocks, it is the hydrothermal solutions saturated with carbon

	Non-serpentinized peridotite Kodor	Slightly serpentinized peridotite Malka	Intensely serpentinized peridotite Malka	Serpentinite without remains of primary minerals Nyzyn-Kol
SiO_2	43.42	37.22	36.58	38.12
TiO_2	—	0.00	traces	0.00
Al_2O_3	1.00	0.59	1.04	0.79
Cr_2O_3	0.45	0.29	0.30	0.32
Fe_2O_3	0.71	3.92	4.91	7.11
FeO	6.96	3.52	2.22	0.43
MnO	0.13	0.31	0.28	0.09
NiO	0.38	0.10	0.13	0.30
MgO	45.62	39.47	38.29	38.90
CaO	0.48	1.16	0.65	0.00
Na_2O	0.10	0.00	0.13	0.00
K_2O	0.04	0.00	0.00	0.00
H_2O^+	0.55	11.88	14.14	12.43
H_2O^-	0.11	1.02	1.08	1.44
Loss on ignition	—	0.93	0.52	0.43
Total	99.95	100.41	100.27	100.36

dioxide that are of decisive importance. At higher temperature phases of metamorphism of these rocks, corresponding to the close of the pneumatolytic—beginning of the hydrothermal phase, at a temperature of about 400°, a process of serpentinization of ultrabasic rocks takes place, in which the decisive part is played by water.

At low-temperature, hydrothermal and hypergene phases serpentinites are metamorphosed, passing into different talc-carbonate rocks, the whole complex of which, as suggested by Zavaritsky (3), is called «listvenites». At this closing phase of metamorphism the decisive part belongs to carbon dioxide.

Thus it follows that in the process of serpentinization carbon dioxide seems to be inert.

If we are to accept the fact of the oxidation of the ferrous iron liberated in the course of serpentinization, it should be assumed that at this phase of metamorphism the activity of carbon dioxide is consumed in the process of oxidation of the ferrous iron by way of a reduction of carbon dioxide to CO. The course of the process of serpentinization and oxidation of the ferrous iron may be described by the following equation:

$$\underset{\text{olivine}}{3Mg_2SiO_4} + Fe_2SiO_4 + \underset{\text{water}}{4H_2O} + CO_2 = \underset{\text{serpentine}}{2H_4Mg_2Si_2O_9} + \underset{\text{haematite}}{Fe_2O_3} + CO$$

The fact of formation of haematite even in the form of micaceous haematite during the metamorphism of ultrabasic rocks has previously been reported by this author from the Sayan range.

Korzhinsky (5) who was engaged in a study of the conditions of magnetite and haematite formation in the processes of metamorphism, also arrived at the conclusion that the rôle of a redox agent in the formation of some or other mineral is played by carbon dioxide. He says: «Out of the amount of oxygen which may be consumed by the reaction from a given volume of natural solution, an essential part is undoubtedly supplied by CO_2, and inversely, CO is capable of producing reduction reactions, being oxidized to CO_2» (p. 65).

A. E. Fersman (4), while discussing the conditions of formation of magnetite and haematite under conditions of pegmatites and ultrabasic rocks, advances the idea that for the precipitation of magnetite a definite concentration of oxygen is

necessary. «In case this be lacking, no magnetite can be formed; ferrous oxide remains in the melt, while ferric oxide, upon a drop of temperatute to 500°, at most to 600°, is segregated in the form of haematite» (p. 139). Elsewhere he says (7) that magnetite forms at a temperature above 550°, while haematite does so at 500—300°.

It is within this temperature range of haematite formation that the serpentinization process takes place, accompanied with an oxidation of the ferrous iron liberated in the course of serpentinization of ultrabasic rocks.

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MINERALOGY

VISHNEVITE, AND NOT SULPHATIC CANCRINITE

By D. S. BELIANKIN, Member of the Academy

In 1916 Larsen and Steiger ([4]) described under the name of sulphatic cancrinite a most peculiar mineral from Colorado, in its hexagonal crystallization and chemical composition somewhat similar to cancrinite, but essentially differing from the latter in that a part of $CaCO_3$ in its chemical formula is equivalently replaced by Na_2SO_4 (Table 1, 1).

Later on, a similar mineral was discovered by Kazakova and Zavaritsky (1929) ([2]) in the Ilmen Mts. in the Urals (Table 1, 3 and 4), and still later, by the present author .(1931) ([1], [3]) in the Vishnevye Gory (Mts.), also in the Urals (Table 1, 5).

In the two Uralian cases the material analysed was not quite monomineral but contained a certain amount of admixtures: in the Ilmen case, of natrolite and cancrinite, and in the Vishnevye Gory case, of scolezite and hydrargillite.

From a detailed calculation of the chemical analysis of the material from Vishnevye Gory the following results were obtained by the author:

1. Weight per cent of the individual components: sulphatic cancrinite—89.0; scolezite—8.6; hydrargillite—2.4.

2. The chemical formula of sulphatic cancrinite:

$$3.2\,(Na_2O \cdot Al_2O_3 \cdot 2SiO_2) \cdot 1\,(m Na_2Cl_2 \cdot n Na_2SO_4 \cdot p Na_2S \cdot q CaCO_3) \cdot 3.3H_2O$$
$$\text{with } m : n : p : q = 1.5 : 79 : 12 : 7.5$$

In accordance with the extreme predominance of Na_2SO_4 over $CaCO_3$ in the Uralian sulphatic cancrinite as demonstrated by the formula and the analyses given in Table 1, it is evident that as a matter of fact we have to do here with no cancrinite, be it even a sulphatic one, but rather with an obviously new mineral for which the present author has suggested the name of «vishnevite». In its ideally pure state vishnevite should have the composition: $3Na_2Al_2Si_2O_8 \cdot Na_2SO_4 \cdot 3H_2O$ (the vishnevite molecule), but in practice it contains an admixture of the cancrinite molecule, $3Na_2Al_2Si_2O_8 \cdot CaCO_3 \cdot 3H_2O$ in its solid solution.

More recently, «sulphatic cancrinite» has been described by Stewart ([5]) from the Loch-Borolan deposit, Scotland (Table 1, 2).

In Table 1 which shows the chemical details of all the above-listed cancrinites, the greatest interest is attached to the CO_2 and SO_3 contents, corresponding to the relative content in each of the cancrinite and vishnevite molecules. If the sum of these molecules in each particular case be put at 100, the following ratios of the said molecules are obtained: 1) 55 : 45; 2) 34 : 66; 3) 23 : 77; 4) 20 : 80; 5) 8 : 92.

It will be seen that the discrepancy here is rather large, the Uralian cases being relatively poor in the cancrinite molecule as compared to those from Scotland and Colorado. How will this be reflected by the respective names of our mineral mixtures?

Table 1

Chemical Composition of Sulphatic Cancrinite from Different Deposits: 1—Colorado, 2—Scotland, 3, 4—Ilmen Mts., 5—Vishnevye Gory (Mts.)

	Weight per cent					Molecular quantities				
	1	2	3	4	5	1	2	3	4	5
SiO_2 . .	33.70	34.76	35.29	34.78	34.53	561	579	588	579	576
TiO_2 . .	—	—	—	—	0.10	—	—	—	—	001
Al_2O_3 . .	29.40	30.81	28.79	28.77	29.06	289	302	282	282	285
Fe_2O_3 . .	—	—	—	—	0.56	—	—	—	—	003
FeO . .	—	—	—	—	0.11	—	—	—	—	001
MnO . .	—	—	—	—	0.09	—	—	—	—	001
MgO . .	—	—	—	—	0.09	—	—	—	—	001
CaO . .	4.18	3.87	4.49	4.27	4.48	075	069	027	023	026
SrO . .	0.08	0.32	—	—	—	001	003	—	—	—
Na_2O . .	18.52	18.90	15.65	15.59	16.51	299	305	252	252	266
K_2O . .	1.45	1.29	4.15	4.90	5.11	015	014	044	052	054
Cl_2 . . .	—	—	—	—	0.09	—	—	—	—	001
SO_3 . .	4.65	5.98	5.76	6.25	5.02	058	074	072	078	063
S	—	—	—	—	0.30	—	—	—	—	009
CO_2 . . .	3.48	1.90	1.01	0.89	0.26	072	043	023	020	006
H_2O^+ . .	4.24	2.30	7.67	7.01	5.35	275	139	423	389	373
H_2O^- . .	0.72	0.20			1.36					
Total . .	100.19	100.28	100.05	99.68	100.02					

If cancrinite and vishnevite, being, as it seems at first sight, bodies ideally isomorphous with respect to each other, were naturally miscible at any ratio, such a perfectly mechanical attack of the question advanced would be possible, indeed. Putting the conventional boundary between mixtures of the series rich and the one poor in the cancrinite molecule at 50 per cent of either component, it may be recommended to retain for the former case Larsen's name of «sulphatic cancrinite», and for the latter to use the more natural name of «carbonate vishnevite», or simply «vishnevite», as proposed by the present writer. The actual state of things, however, suggests a different solution.

As a matter of fact, no complete isomorphous miscibility of vishnevite and cancrinite is observed. While vischnevite dissolves readily cancrinite, the latter does not at all take in the molecule of vishnevite. In the majority of the numerous chemical analyses of cancrinite known, the value of SO_3 is not given at all, and if shown, then—at least in the more recent and reliable analyses—it does not exceed 0.1 per cent [cf., for example, the cases of cancrinite from Iron Hill, Colorado, cited by Stewart ([5]) after Larsen and Foshag, 1926 (0.03 per cent SO_3 corresponding to 0.3 per cent in the molecular sum of CO_2+SO_3) and of cancrinite from Dodo, Korea, after Kozu, 1931 (0.08 per cent SO_3 or, which is the same, 0.7 per cent in the sum of CO_2+SO_3)]. The demarkation line between cancrinite and vishnevite is thus quite different, and even in the case of the sulphatic cancrinite of Larsen and Steiger ([4]) it lies on the side of vishnevite.

In good agreement with the absence of a complete isomorphism between vishnevite and cancrinite is also the fine twinning lattice of the microcline type observed by the author in the Vishnevye Gory mineral (polymorphism or, at least, polysymmetry). Characteristic in this connexion is also the anomalous biaxiality shown by Stewart in the Scottish sulphatic cancrinite (that is, vishnevite).

To sum up, all the cases of sulphatic cancrinite described above should be referred to vishnevite.

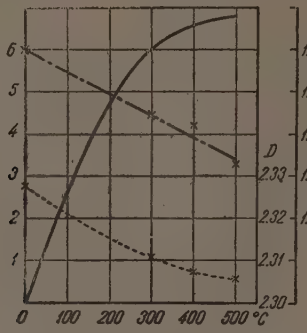
In addition to the characteristic of the Vishnevye Gory variety of this mineral as given by the author in his previous work, we shall cite here unpublished data of his, in collaboration with Nikogosian, on hydrous silicates showing among other things the zeolitic type of the water in vishnevite (Table 2 and figure).

Table 2

Loss of Water, Refraction (N_0) and Specific Gravity (D) of Vishnevite from Vishnevye Gory at Various Temperatures

Temperature °C	Loss of H_2O, weight %	Refraction N_0	Specific gravity D	Note
15	—	1.489	2.328	At all temperatures the same extremely slight refraction is retained as in raw vishnevite: $N_o - N_e \leqslant \leqslant 0.004$
150	3.51	—	—	
200	4.99	—	—	
250	5.53	—	—	
300	6.01	1.474	2.310	
350	6.41	—	—	
400	6.61	1.472	2.308	
450	6.71	—	—	
500	6.71	1.463	2.306	

In the light of these data, of considerable interest is the question as to the temperature conditions of the formation of the vishnevite from Scotland, with its 2.50 weight per cent of water, parallel to the water content of the Uralian vishnevite upon being heated to about 200° C. That these conditions could actually have



——— H_2O loss in weight %. — — — specific gravity D. —.—.— refraction N_0. Along the vertical axis: H_2O loss in weight %

been rather high-temperature ones, may be inferred from the information by Stewart, that his vishnevite did not only form one of the chief components of the pegmatite bodies dissecting the borolanites, but occurs also as a rather common component in the schliers of the borolanites themselves. The same is evidenced, finally, by the paragenesis of vishnevite in pegmatites with orthoclase, melanite and black mica with a total absence of any indication to its secondary nature in this particular instance.

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GENETICS

MARMOT HYBRIDS

(ON THE QUESTION OF INTERSPECIFIC HYBRIDIZATION IN NATURE)

By V. S. BAZHANOV

(Communicated by L. A. Orbeli, Member of the Academy, 14.VII.1943)

When examining large lots of marmot furs on stock at the Kuybyshev, Chkalov, West-Kazakhstan and Aktiubinsk districts, we occasionally ran across such individuals as combined characters of *Citellus major* Pall. = *C. rufescens* with those of *C. pygmaeus* Pall. In a number of localities these species inhabit the same places. Those furs made us think of a hybrid origin of the individuals. Sviridenko ([5]) has already reported of a hybrid between the marmot *C. pygmaeus* and *C. suslica* caught by him.

In the light of these data our attention was attached to a rather small marmot resembling *C. rufescens*; the animal was met on June 20, 1931, near village Verkhnyaya Dneprovka of the Chkalov district, 120 km eastwards the town Chkalov, on the left bank of the Ural river, at the boundary between a wormwood pasture and a steppe overgrown with various cereals and grasses. The animal had a highly piercing squeak uttered in two times, which is not peculiar to this species; when closely examined, it was found to show characters both of *C. rufescens* and *C. pygmaeus*.

The size of the rodent was an intermediate one between the two species. The colour of its back and tail, as well as the fluffiness of the latter were like those of *C. rufescens*. The «cap» on its head was no silvery one, but with separate silvery hairs. Its squeak resembled that of *C. rufescens*, though somewhat higher and shriller; but occasionally it was uttered in two or three times, strongly reminding the voice of the small marmot, called the «whistler».

When kept in a cage under observation, the animal showed a livelier behaviour than that typical of *C. rufescens*, reminding *C. pygmaeus* again.

According to all its peculiarities this marmot was an obvious hybrid between the two species, with a prevalence of the characters of the larger one. After a few days the animal escaped, which prevented us from proceeding in the analysis of its biological and taxonomical characters.

A comparison of the intermediate heredity between *C. rufescens* and *C. pygmaeus*—the dominance of the characters of the former—with palaeontological evidence for *Citellus major* ([2–4]) points to a more remote age and, consequently, a greater primitivity of *C. major*.

The case of natural hybridization points to a close genetic relationship between *C. major* and *C. pygmaeus*. Isolated hybrids may probably be met in nature between other species of marmot, occupying common areas of habitation.

In 1943 I found that in the northern part of the Gurjevsk district (village Kara-Kul of the Makat region) *C. major* lives together with *C. fulvus* Licht. It should be noted, besides, that the southern boundary of the area of distribution of the

former passes through those localities, to the north of Kzyl-tau. Here, among the furs on stock, one may frequently run across such as bear characters intermediate between the two species named above, i. e. as it were hybrid ones. According to the information obtained from local specialists, such individuals may occasionally make up about 2—3 per cent to the total number of *C. fulvus* caught. It seems most probable that these individuals are only F_1 hybrids.

Thus, some of the species of the genus *Citellus* are undoubtedly nothing else than ultimate stages of the evolutionary divergence of subspecies which have but recently attained specific differentiation.* This is also evidenced by the fact that the young of *C. rufescens* display a coloration of the head which is sharply expressed in adult individuals of other subspecies of *C. major*, viz. in *C. major ungae*, *C. m. erythrogenus* and even in *C. suslica guttatus*.

When investigating the taxonomy and phylogeny, especially in polymorphous genera, we think it advisable to take into account, aside from morphological and colour characters, the voice of the animal, too. The squeak of the marmots is, of course, a taxonomical character, for the variations in their recitative must certainly be due to a peculiar specific structure of their vocal chords (which is a morphological character), and to the specific peculiarities of the activity of their nervous system. Interspecific vocal differences must be more pronounced than those between subordinate taxonomic units.

It would be of interest to apply experimental analysis to the mode of inheritance of characters in the case of hybridization of species belonging to polymorphous genera.

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* The same idea has been suggested by Ognev ([1]) with respect of interspecific hybrids between predatory animals.

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PLANT PHYSIOLOGY

SEXUALIZATION OF PLANTS AS AFFECTED BY DIFFERENT MOISTURE CONDITIONS OF THE MEDIUM

By E. G. MININA and P. P. MATZKEVICH

(Communicated by A. N. Bach, Member of the Academy, 5.VI.1943)

The course of age variation in plants is strongly affected by the moisture of the surrounding medium (1). It has been observed (2, 3) that the most susceptible to moisture conditions are plants at the period of the formation of their generative organs.

Insufficient humidity of soil or air brings about profound functional disturbances of the plant's sporogeny, leading to phenomena of abortiveness. External signs of this state must not be necessarily present; thus, in our experiments developed wheat flowers lost their capacity to fertilization even in those cases when after a short stay under conditions of a dry climate they were stored in a favourable medium.

This was especially conspicuous in the zone of the ear. It remains uncertain, however, whether this phenomenon should be interpreted as a result of a different rate of ripening of the androcium and gynoecium, the condition being known as dichogamy, or whether it is due to some other processes of more profound nature. In a most explicit way this question could be solved on dioecious plants.

In one of his articles Lubimenko (4) has suggested the idea that those shifts of sexes as are brought about by the external medium, should be accounted for by nothing else than a different rate of the form-building process. And what is frequently called male sexualization is, according to his opinion, merely some lagging in the general tempo of development under the given conditions, and consequently a delayed appearance of female flowers.

Hence rejuvenated plants are always likely to show a prevalence of male sexualization.

Our experiments were carried out in 1940 on *Cucumis sativus*, variety Nerosimye, under conditions of a greenhouse, in six replications. The relative air humidity was controlled by means of chambers of an artificial climate, which in the subsequent will be called the I humid and the II dry chamber (Table 1). The deviation of relative air moisture from the known one made up 7 per cent, that of temperature, 3° C.

The soil was kept moist throughout the growing period at a level of 80 and 40 per cent to total moisture capacity.

Table 1

Chambers	Relative air humidity in %	Air temperature in °C
I humid .	89	23
II dry . . .	50	30

According as the plants were advancing in their development, the moment of setting and formation of buds in the axil of the successively appearing leaves was watched under a binocular microscope. According to the stage we were interested in, the plants were placed into chambers of artificial climate for a definite number of days. The effect of various air humidity was tested during three different periods.

First period: from the setting of the bud until the formation of the parts of the flower. By this time the plants had only cotyledon leaves, and their first true leaves were just opening. Upon preparing, initials of almost set leaves could be detected. Duration, 5 days.

Second period: from the beginning until the end of formation of the lower parts. The plants had now two developed true leaves and ten set leaves. Duration of treatment, 15 days.

Third period: from the end of formation of flower parts till its opening. A total of eighteen set leaves present, inclusive of eight fully developed. Duration, 15 days.

Each period corresponds to a given group of the best developed blossoms.

After their stay in the chambers, the plants were put on shelving in a greenhouse, and their mode of flowering was observed daily. The results obtained were subjected to statistical treatment, which enabled us to conclude that the formative effect of varying air humidity is the most efficient during the second period, i. e. when parts of the flower of a young plant are being formed. When the treatment is applied at an earlier date, or to buds of older plants, it is much less efficient, and may have no apparent result at all.

The results of a test carried out with the second period are summarized in Table 2.

Table 2

Number of Days that Elapsed until the Appearance of the First Male or Female Flowers

Sex	Chamber	
	I humid	II dry
Male	27	23
Female	35	37
Difference in days	8	14

As may be seen from this table, the effect of dry climate was to accelerate the appearance of male flowers, while that of female was found to be impeded. The effect of a humid climate was entirely different: here the rate of the appearance of female flowers was increased, whereas that of male ones was lagging behind.

If in the former case the difference between the dates of appearance of male and female flowers made up 14 days, in the latter it was reduced to 8 days only.

A still more conspicuous difference in the shift of sex tendencies is evident from the ratio between the total number of male and female flowers. The appearance of flowers was recorded every second day throughout the growing period, and entered in the flowering scheme of each individual plant separately.

On the ground of the data obtained one is led to conclude that the rise of air humidity results in the plants both in a more rapid and a more profuse appearance

Table 3

Chamber	Ratio ♂/♀ flowers			
	25.VII	31.VII	5.VIII	10.VIII
I humid	10 : 1	12 : 1	12 : 1	10 : 1
II dry	85 : 1	109 : 1	57 : 1	35 : 1

of female flowers, as compared to plants kept under conditions of relatively dry air.

The rate of formation of male or female flowers, as well as the ratio between their numbers are indices characterizing the trend of the sexual process which takes place in the organism. We have thus shown that along with an increase in the relative air humidity, sexual development assumes a course towards a greater manifestation of female tendencies. In this case a female sexualization of the organism is observed.

The effect of variations in soil humidity is similar to that of the air (Tables 4 and 5).

Table 4

Soil humidity in % to total moisture capacity	Number of days until appearance of first flowers			Level of setting of first flowers		
	♂	♀	Difference in days	♂	♀	Difference of levels
80	26	33	7	1.9	11	9.1
40	27	40	13	2.3	19	15.7
Difference	1	7		0.9	8	

Table 5

Ratio ♂/♀ Flowers

Soil humidity in % to total moisture capacity	31.VII	5.VIII	10.VIII
80	13 : 1	14 : 1	17 : 1
40	58 : 1	68 : 1	58 : 1

In plants grown at different soil humidity male flowers appeared simultaneously, while the rate of appearance of female flowers differed greatly. With a 80 per cent soil humidity the difference between the rates of appearance of male and female flowers is almost a half of that with a 40 per cent soil humidity. As may be seen from the ratio of male to female flowers, shifts of the sexual tendencies towards female sexualization were observable throughout the growing period. Thus, the humidity of soil, as well as that of air, has a strong effect upon the trend of sexualization in plants. The effect of a humid soil is to promote a more rapid and strong manifestation of female sexualization, as compared to the plants grown in drier soils.

Observations carried out on such characters as are typical of the age variation of plants, such as rate of formation of metameres, duration of stages, leaf-shape, have shown that both under conditions of increased air humidity and soil moisture the course of ageing of the organism is delayed considerably.

Typical features connected with the appearance and development of sporophylls of both monoecius and dioecious plants make us think of sexualization phenomena as obeying the laws of age variations taking place in the organism. It seems, however, not correct to speak of a relation between the two phenomena. As it may be seen from our experiments, the formation and development of male or female flowers may stand in no relation to the age variation of a plant, but rather obey some other regularities operative in the life of its organism. In the case of an increased rate of the general ageing process and of an earlier setting in of the generative stage, the character of sexualization may be entirely incongruous with this rate. The mechanism of sexualization seems to be related, aside from ageing, with some other processes that are still unknown.

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PLANT PHYSIOLOGY

INTERACTION BETWEEN ROOTS AND SOIL COLLOIDS AS A PROBLEM OF THE PHYSIOLOGY OF MINERAL NUTRITION OF PLANTS

I. UNSTABLE EQUILIBRIA IN THE CATION EXCHANGE BETWEEN THE ROOTS OF PLANTS AND THE SOIL COLLOIDS

By E. I. RATNER

(Communicated by A. N. Bach, Member of the Academy, 5.VI.1943)

The knowledge of those complicate interrelations that since the first day of a plant's development arise between its root system and the colloidal complex of the soil is of outstanding interest: it must be helpful in investigating the mechanism of absorption by the plant of elements of mineral nutrition from the soil, as well as in solving a number of problems bearing on fertilization and melioration of soil. Notwithstanding the paramount importance of this problem, however, the questions bearing on the interaction between higher plants and the soil colloids were left outside the field of vision of the plant physiologist. Yet, it is just this aspect of the matter, as being the central point of the problem of colloidal-chemical phenomena in the soil, that has been stressed with particular emphasis by representatives of agrochemistry and pedology ([1], [2]).

Two deeply inracinated ideas prevented the physiologist from approaching the question of the interaction between the plant and the solid phase of the soil. This is the idea as to the transpiration flow as a fundamental agent of salt supply to the plant, and that of the plant being unable independently to use up the nutrient substances which have been accumulated by the colloidal soil complex.

At the time being there is, however, a sufficient bulk of information which point, on the one hand, to the important part played by the phenomena of metathetic adsorption in the process of absorption by the plant of mineral elements from the external solution, and, on the other hand, speaking of the plant's capacity successfully to assimilate (otfen more completely than from solution) mineral substances adsorbed by the soil, without their preliminary displacement into solution by means of an external agent.

Moreover, work carried out along this line resulted in the accumulation of new data which permitted of a wider approach to the problem of interaction between the plant and the solid phase of the soil. Thus, when investigating the accessibility to the plant of the exchange calcium of the soil, we became aware of the fact ([3]) that under definite conditions (a high degree of saturation of the colloidal complex with sodium along with its low saturation with calcium) the interaction between the roots of the plant and the soil does not help the plant to use up the calcium available in the soil; on the contraty, it is leading to an inverse motion of the calcium, from the plant into the soil, thus bringing about a deficiency of this element in the seedlings, accompanied with specific symptoms of calcium starvation.

This fact could scarcely be put in agreement with the soil solution interpreted as an inevitable intermediary agent between the plant and the solid phase of the soil, for it makes us assume the existence of another, more intimate interaction between the roots and the colloids of the soil.

The phenomenon of desorption of cations from the plant in the course of interaction between its roots and the colloidal adsorbents has recently been studied in detail in most interesting works by Ienny and his co-workers ([5],[4]). The writers were led to the development of a theory of contact exchange with ions between the roots and the colloidal adsorbent, as of a phenomenon underlying the using-up by a plant of exchange ions of the soil.

Another trend in science, which opened the question as to a direct interaction between the plant's roots and the colloids of the soil, was the study of the colloidal-chemical properties of the vegetable cell. As a crucial point on this way we are inclined to consider the appearance of the work by Kostychev and Berg ([6]) who showed that a considerable part of calcium in a plant is contained in an adsorbed condition. Kostychev correctly estimated the possible import of this fact for the understanding of the relations that exist between the plant and the solid phase of the soil. In the paper cited, as well as in his textbook of plant physiology, he wrote: «these observations permit to assume that to the soil's absorbing complex the plant opposes one of its own, whose nature still remains obscure».

In the subsequent the existence in plants of cations largely in adsorbed condition has been demonstrated by a number of writers ([7], [8], [11]). In a newly published paper by Mason and Phillis ([9]) an attempt was being made to estimate this fraction of cations in a plant from a physiological viewpoint. It is essential to emphasize that in the latter work we find a precise statement, *viz.* the higher the total content of Ca and K in the leaves of a plant, the larger is the portion of these cations in an adsorbed condition. These data reveal another feature of the colloidal-chemical properties of the protoplasm, which is highly important for the question we are interested in, *viz.* its gradually increasing saturation with cations according as the total content of the latter in the cell augments. Hence an array of conclusions important for the understanding of the process of interaction between the plant and the soil colloids.

If the content of cations in a cell is low, the larger part of them is contained in the cell sap, and only a small one in adsorbed condition. In this case the exchange capacity of the plasm with respect to cations is largely occupied by hydrogen which is continually produced in the cell in the process of respiration. It is by way of this hydrogen that the desorption of the cations from the plasm into the cell sap takes place. Therefore in the case of a low content of cations the plant displays a very high activity in the desorption of cations from the soil's colloidal complex, exchanging these cations for hydrogen ([10]). Quite different is the picture in the case of an increased total content of cations in the cell. In this case the saturation of the cell's colloidal elements with cations increases gradually, owing to which their further absorption by the roots from the colloidal complex cannot possibly take place unless the latter is highly saturated with these cations. If the colloidal complex of the soil shows a low degree of saturation with these cations, while the colloids of the cell are highly saturated, an inverse process may take place, *viz.* the desorption of a given cation by the soil from the plant.

Let us cite a few facts from our experiments of 1940, which go to substantiate these conclusions.

Experiment I. The plant (barley «Wiener 01163») was being grown in water cultures, at various concentrations of potassium in the nutrient solution. As a result, plants have been obtained strongly varying as to their saturation with potassium. When three weeks old, they were made to interact, after the roots had been thoroughly washed off the nutrient solution, in one set with a KCl solution, and in another, with an especially prepared suspension of soil saturated to 10 per cent of its exchange capacity with potassium; the remaining 90 per cent were saturated with calcium (25 per cent) and hydrogen (65 per cent).

In both cases the amount of potassium supplied to the plant either in the form of KCl or in the exchange form, made up 120 mg per pot. After a 48-hour interaction of the roots with the source of potassium, the plants were subjected to analysis for the content in them of this element. The results are tabulated below.

Table 1

Concentration of K in solution (in Helriegel's norms) given to the plant when grown previous to experiment	Content of K in plants previous to experiment, in %	Absorption by plants of K in mg after a 48-hour interaction with	
		KCl solution	soil suspension
1/4	3.052	24.65±1.51	14.92±0.72
1/2	4.207	9.93±0.77	2.00±1.21
1/1	7.251	0.31±1.44	—6.35±0.94

As may be seen from Table 1, when the saturation of the plant with potassium is the lowest, their activity in desorbing this element from the soil's colloidal complex is very strongly pronounced. When the experimental saturation is a medium one, the plants are found scarcely capable to desorb this cation from the colloidal complex of the soil, although its absorption from a KCl solution proceeded very intensely. And finally, with a further increase of the saturation of the plants with potassium, there is already desorption of this element by the soil from the plant.

Experiment II goes to illustrate the same state of affairs with respect to calcium. Being especially salient in roots, we will content ourselves by giving here corresponding data for roots only. Interaction of plants with suspension of soil proceeded under the same conditions as in experiment I and lasted 36 hours. The soil was saturated up to 30 per cent of its exchange capacity with calcium, the remaining 70 per cent being given to hydrogen. The plants were grown previous to the experiment under a sharply different supply with calcium, the differences being still more sharply pronounced than in the preceding test with potassium; in the first line this told upon the content of calcium in their roots. The results of the test may be expressed by the following figures (Table 2).

Table 2

Previous to test (control) in % to abs. dry substance	Upon a 36-hour interaction with soil suspension	
	in % to abs. dry subst.	in % to control
0.486	0.264	142
0.657	0.650	99
1.902	1.095	58

The same picture as that offered by the preceding test is still more conspicuous in this case.

Lastly, if the ability of the colloidal complex of the soil to absorb and stably fix calcium is especially sharply pronounced, which is the case with a high saturation of the colloidal complex with sodium ([3]), then the desorption of calcium from the plant during the interaction of its roots with a suspension of such soils is observable even in those plants as are poorly saturated with this cation. The following test goes to illustrate this statement.

Experiment III. The same barley «Wiener 01163» grown under different degrees of supply of calcium, was made to interact with a suspension of the same black-soil, saturated up to 30 per cent of its exchange capacity with calcium,

and up to the remaining 70 per cent, with sodium. The other conditions were the same as in experiment II.

The analysis revealed the following content of Ca in the roots (Table 3).

Table 3

Previous to experiment (control) in % to abs. dry substance	Upon a 36-hour interaction with soil suspension	
	in % to abs. dry subst.	in % to control
0.186	0.120	65
0.657	0.566	86
1.902	1.087	57

The trend of the cation exchange between the roots of the plant and the soil colloids is thus determined by the degree of saturation of the vegetable tissues with the given cation, on the one hand, and by the degree of saturation and stability of the bond of this cation in the colloidal complex of the soil, on the other hand. If a low saturation of the plant with a given cation is combined with a high saturation of the colloidal soil complex with the same cation, then the absorption of this cation by the plant from the adsorbed fixed condition may proceed even more completely than from a solution, which may be illustrated by the following test.

Experiment IV. The barley «Wiener 01163», after being preliminarily grown for three weeks in water cultures of Helriegel's medium taken in a quater of the usual norm, was made to interact during 48 hours with a KCl solution, with a suspension of soil saturated up to 10 per cent of its exchange capacity with potassium and to 90 per cent with calcium, and with a suspension of the same soil saturated up to 50 per cent with potassium and up to 50 per cent with calcium. In all cases the amount of potassium supplied to the plants either in solution or in the exchange form made up 120 mg per pot. As a result, the following quantities of potassium have been found to be absorbed by the plants (in mg):

From KCl solution	24.65±1.51
From soil suspension saturated with 10% of K plus 90% of Ca	15.09±1.43
From soil suspension saturated with 50% of K plus 50% of Ca	31.78±0.13

These data need not to be commented.

The plant's high activity in absorbing exchange cations of the soil in the case of a low saturation of its tissues with these cations has a certain limit, however, at least in the case of potassium. If the saturation of the plant with potassium is so low that the deficiency of this element calls forth considerable alterations in the general state of the plant, which is expressed by the specific features of potassium starvation, then the plant's activity in absorbing the exchange potassium in the soil does no more increase, but drops instead. This may be illustrated by the following experimental data.

Experiment V. In our experiment III described above, along with a set of plants grown on a $^1/_4$ of the norm of Helriegel's medium we had also a set of pots in which plants were grown in a medium with traces of potassium only ($^1/_{30}$ to Helriegel's norm). The rest of nutrient substances were supplied in a $^1/_4$ to Hel-

riegel's norm. The plants of this set which at the age of three weeks showed clear-cut symptoms of potassium deficiency, were treated in the same way as those of experiment III, under analogous conditions and synchronously with it. As a result, the following data were obtained as to the absorption of potassium by plants of the two sets from KCl in solution and from exchange condition.

Table 4

	Absorption of potassium in mg	
	by plants grown on a $^1/_4$ of Helriegel's norm	by plants grown on a $^1/_{30}$ of Helriegel's norm
From KCl solution .	24.65±1.51	24.28±0.66
From soil suspension saturated with 10% K plus 90% Ca	15.09±1.43	9.94±0.59
From soil suspension saturated with 50% K plus 50% Ca	31.78±0.13	20.27±0.53

As may be seen from this table, the plants of the two sets absorbed almost equal quantities of KCl from solution, whereas from the suspension of soil the plants of the second set absorbed less potassium than the plants of the first set.

The complex of the data given here makes one assume that in the course of interaction between the roots of the plants and the soil colloids some highly mobile dynamical equilibria find their expression in the exchange of cations between the plant and the soil. As a result, at any given moment of the plant's development there may take place either absorption of the given cation by the plant from the soil, or the inverse process of its absorption by the soil from the plant.

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ZOOLOGY

ADAPTIVE IMPORTANCE OF THE FIRST PAIR OF LEGS OF THE MOLE-CRICKET (*GRYLLOTALPA GRYLLOTALPA* L.)

By D. N. KOBAKHIDZE

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The genus *Gryllotalpa* includes three palaearctic species (*G. gryllotalpa* L., *G. africana* Palisot, *G. unispina* Sauss.) which in the main inhabit the soil, only at times coming out to the surface of the earth; males can fly. The mole-cricket developed organs corresponding to such a mode of life: its first pair of legs became of true digging type for the purpose of progression in the soil, its second and third pairs are of the running type; these two pairs are completely sufficient for moving on the surface, since for flying the mole-cricket is armed with well-developed wings. We shall investigate in the present work the first pair of legs of *G. gryllotalpa* L.

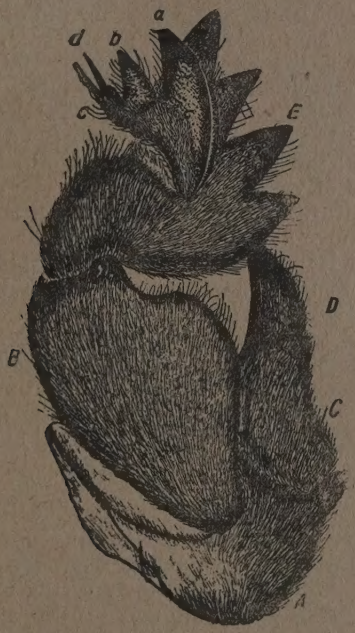
As shown by observation, the following elements of ecological conditions are necessary for an optimal development of the mole-cricket: lowlands, moist, silty soils near the banks of rivers, lakes, canals, etc., i. e. comparatively light soils, rich in nutrient substances and sufficiently moist. The biocoenotic environment of these types of habitation, particularly the useful complex of vegetation and fauna, supply the mole-cricket liberally with various species providing food at any season of the year.

The progression of the mole-cricket in these typical habitations is greatly facilitated.

It is well known that there are two ways of progression of insects in the soil: 1) the passive way or the using of free hollows between the hard particles of soil (when the body of the insect is comparatively small, for example, the *Collembola*), and 2) the active way, when the insect makes its way through the soil (the body of the insect being comparatively large, for example, the *Elateridae*). In so far as the body dimensions of the mole-cricket prevent its moving in the soil in the first way, it is adapted to progression in the active way: the mole-cricket makes its way during progression, and its first pair of legs is adapted for this very purpose.

Naturally enough, a complete adaptation of the species to its environment cannot take place as a result of a progressive evolution of a single organ. For its progression in the soil with the purpose of finding food, multiplying and avoiding the pessimal thermic regime, the mole-cricket needed a first pair of digging legs, a comparatively stream-line, cylindrical shape of the body with a strongly developed thorax and accessory, so-called fortifying, accomodations; these are provided in the main by the third pair of legs. On each tibia of the third pair of legs—on their inner surface—there are 4—5 sufficiently strong pincers and on the outer surface—one. Moreover, each pair of legs is armed with five spurs; 3 on the inner and 2 on the outer side.

As it is well illustrated by the figure, the evolution of the first pair of legs of the mole-cricket went so far that the fore legs do not resemble the usual, ambulatory type. The leg as a whole is very broad, strong, strongly chytinised, armed at its end with a whole system of sharp endings (indents), of which the lower ones are at the same level (the end of tibia) and consist of four separate endings (indents), two of them being movable and two stable. The tarsus is also located here.



We must call attention on the fact that all drawings of the tarsus known in literature ([1–3]) fail to give the real picture, and must therefore be corrected. The fore tarsus consists of three joints. The first joint (figure, *a*) is very broad, sharp, resembling a knife, slightly curved and deformed to such a degree as to bear no likeness with a usual joint of the tarsus of either of the remaining pair of legs. The second joint (*b*) is less broad, less sharp, slightly curved, and less deformed. The third joint (*c*) preserved the usual insect ambulatory type, ending with two strong and sharp claws (*d*). There is comparatively little hair on the surfaces of the tarsus (*a* and *b*); the longest and strongest hairs are located at the edges, but the very endings are absolutely hairless.

Supposing the right leg of the first pair of legs of the mole-cricket being in one plane, the configurations of its basic composing parts represent the following approximate correlations (in per cent): *A*, coxa 19.4 (diminished on the drawing as it is partly hidden behind the femur); *C*, trochanter 8.7; *B*, femur 33.1; *D*, trochanter spur 3.7; *E*, tibia 28.3; *F*, tarsus 6.1; *d*, claws (both) 0.1. Consequently, femur and tibia cover approximately 61.4 per cent of the total area of legs, composing their broadest and strongest part, and the tarsus, the smallest. Notwithstanding this fact, the direct function of digging the soil is performed by the tibia and partly by the tarsus. Sharp endings (indents) of the tibia are hairless, they are strongly chytinised and slightly curved outwards. Almost the whole of the leg, except the sharp endings, is covered with hairs of a various thickness, these hairs being the longest and strongest at the edges and being evidently destined for sweeping the ways dug in the soil.

Thus, the main functions of sub-soil progression of the mole-cricket are performed by the first pair of legs, their structure being entirely adapted to that purpose.

As soon as the mole-cricket happens to be on the surface, it immediately begins to work with full energy using its first pair of legs in a simultaneous outward movement, digging the soil and throwing the earth out, in order to open the way for underground progression. The digging apparatus being very succesfully adapted to such a purpose and the basic habitat of the mole-cricket consisting of light and comparatively moist soils, such work is carried on succesfully, and so the mole-cricket can quickly disappear in the soil. When meeting on its way roots of plants or other obstacles that cannot be overcome with the aid of indents of its tibia only, the tarsi come to help succesfully cutting small roots. Naturally, besides the digging with the first pair of legs, progression is facilitated by a strong structure of the whole body resting on reliable pincers of the third pair of legs.

The speed of the mole-cricket's progression in the soil depends on several causes, the main of which are: the age of the insect and the degree of the development of the digging apparatus, the soil structure and the degree of its moisture, the cultivation and the degree of vegetation cover, etc. The older the insect and the stronger its digging apparatus, the more successful will be the movement (at the beginning, larvae do not move at all, remaining in their mother's nest); the lighter the soil and the higher its moisture (not up to complete saturation), the more successful will be the movement; the mellower is the soil and the less the vegetation on it, the less obstacles will there be for progression.

Consequently, with the transition to subterranean life, the organism of the mole-cricket underwent considerable morphological modifications, and special organs for sub-soil progression were developed—the first pair of legs and accessory organs in the other parts of the body for a better adaptation in the process of selection. All parts of the first pair of legs are deformed and have lost the structure of the common ambulatory type of insect legs (except the last joint of the tarsus and the claws).

Taking into consideration the ecological distribution requirements of the mole-cricket, it is necessary to state that the existing morphological structure and biological peculiarity is quite adaptive and guarantees for its life regime in the soil. The noticed comparatively high plasticity of the mole-cricket with respect to ecological conditions and its ability to move in the space by other means (on the soil surface, capacity of flying and swimming) is a guarantee of its preservation as a species.

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